Field Calculations for Ring Cooler

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Ring Cooler Geometry

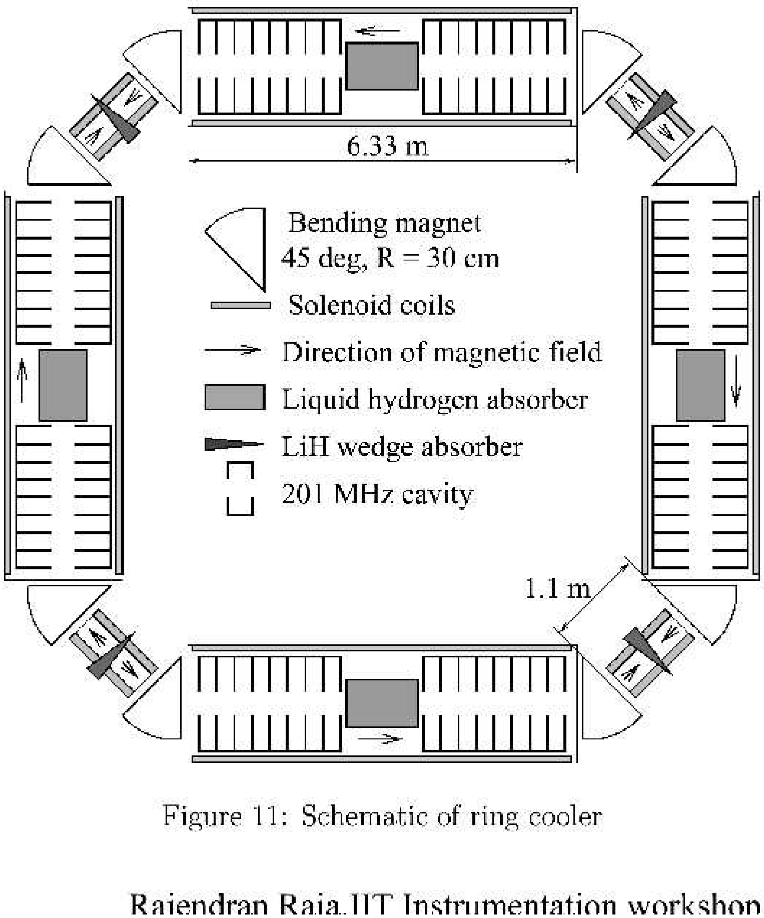
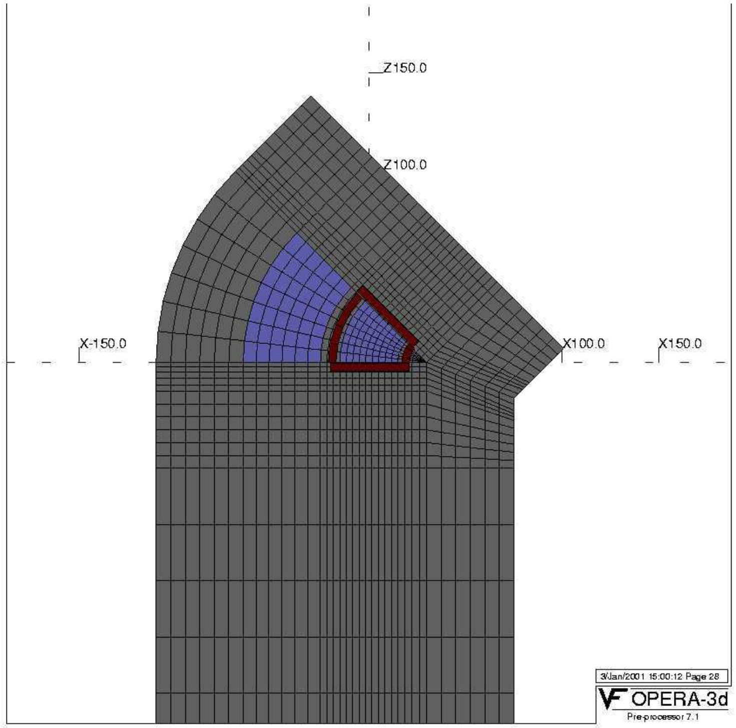


Figure 11: Schematic of ring cooler



TOSCA finite element program models one octant of ring.

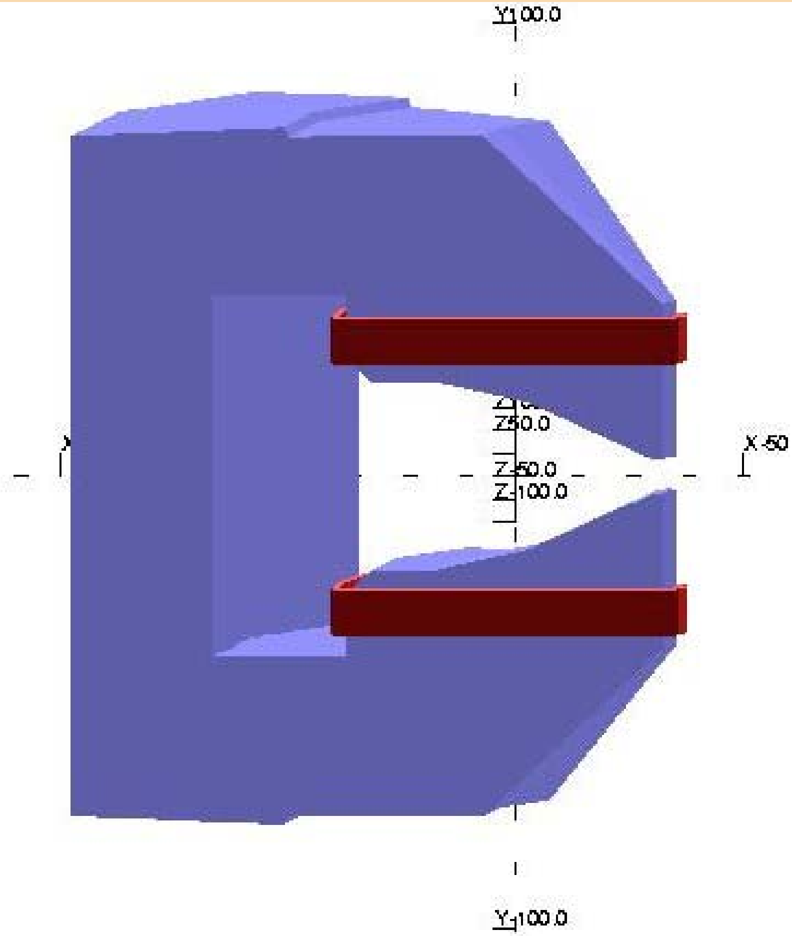
Approach to Field Calculations

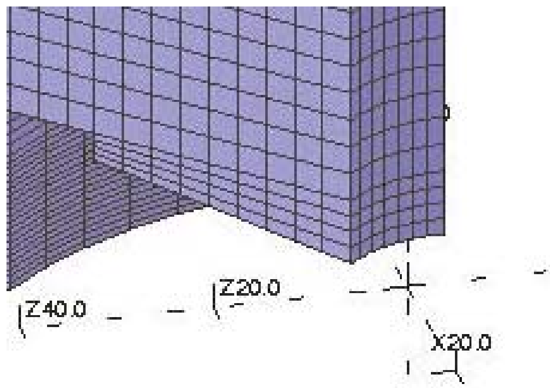
- The smallest *geometric* symmetry unit is the octant. This is not the smallest *magnetic* symmetry unit because of the field flips.
- If we can assume that the magnet iron is linear we can separate the octant into sub-regions:
  - Large Solenoid
  - Wedge Dipole
  - Small Solenoid
- We can calculate the contributions of these magnets and add them.
  - We can evaluate how good an approximation this is.
- The alternative would be to treat the system as a whole.
  - The finite element problem would have ~1000000 nodes and would take a very long time to run!
  - This is not a simple topology for programs like TOSCA.

Dipole Magnet Specifications

- The preliminary parameters of the bending magnet as provided:
  - Bending Radius R_{bend} =52 cm
  - Bending Angle $\Theta_{bend} = 45^{o}$
  - Field Strength B = 1.46 T at reference radius
  - Normalized Field Gradient: $$\frac{dB}{dr}\frac{r}{B} = -0.5$$
    - $dB_y/dx \times (R/B_o) = -0.5$
  - Radius of aperture $R_{aperture}$ = 17 cm.

Sketch of Dipole Magnet





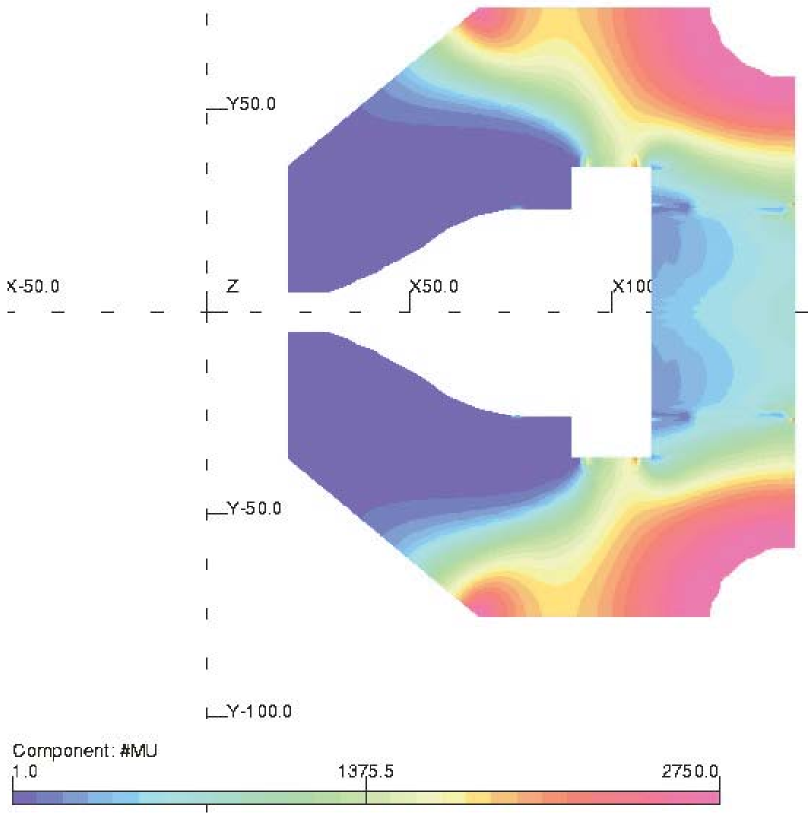
Pole face is shaped to achieve required gradient

The design of the wedge magnet is from P. Schwandt (dated 30 Jan 01).

It has been revised.

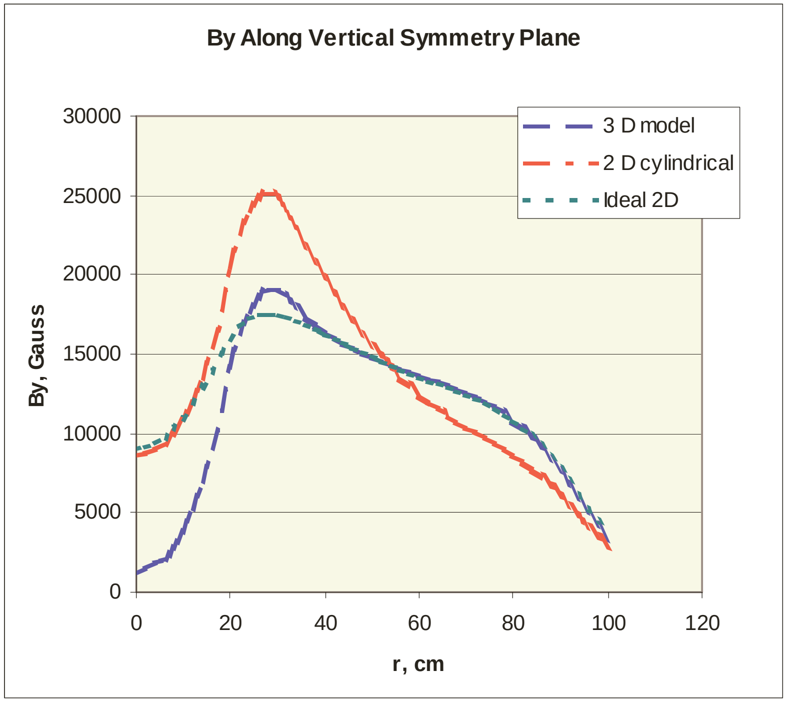
Saturation in Dipole Magnet

- Figure shows the permeability for the vertical midplane of the magnet.
- μ<10 on inner edge of the aperture.



B_y along Vertical Symmetry Plane

- Figure shows three curves:
  - Ideal Field:
    - 2D field from shaped iron pole and effective yoke width.
    - Calculate index=0.473
  - 3D Field Calculation
    - Calculation using TOSCA
    - Gives index=0.47
  - 2D cylindrical Calculation
    - Uses same pole profile, but has closed cylinder out of plane.



Dipole Field along Reference Path

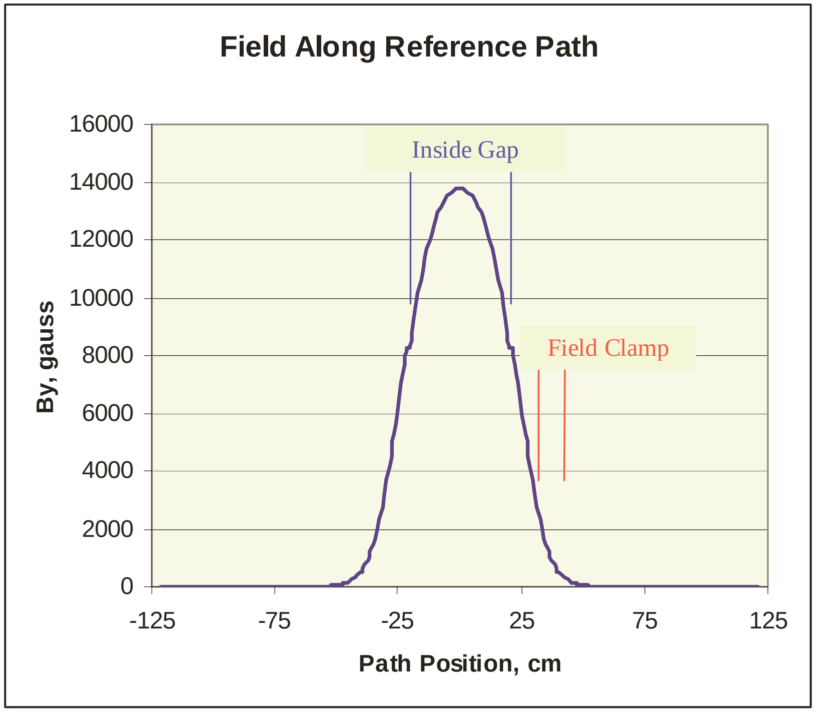


Figure 3: B_y along central reference path.

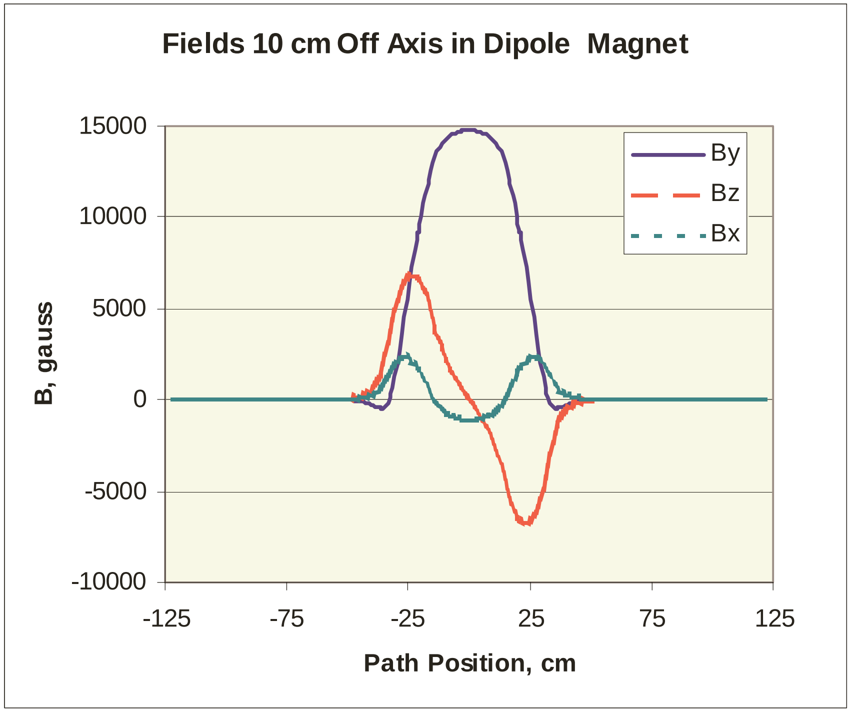


Figure 4: Field components for a path displaced 10 cm vertically from the reference path

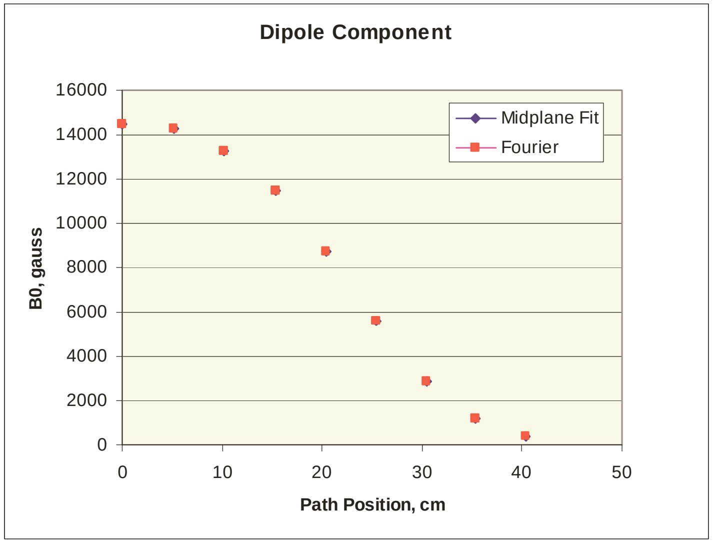
Avoiding a 3D Map

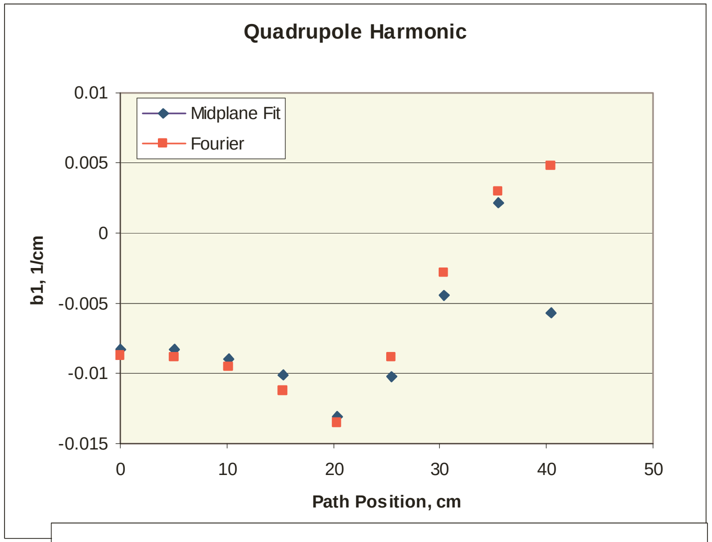
- The 2D part of a long accelerator magnet is traditionally parameterized by Fourier harmonics.
- A generalization of the traverse field that takes into account the s dependence of the field has the form:

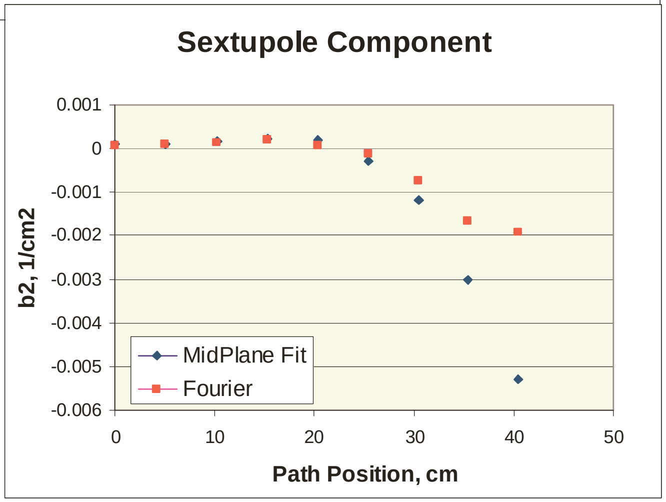
$$B(r,\varphi,s)=\left[K_1(z)-\frac{3}{8}\frac{d^2K_1}{ds^2}r^2+\frac{5}{192}\frac{d^4K_1}{ds^4}r^4+\cdots\right]\sin(\varphi)+$$

$$\left[K_2r-\frac{1}{6}\frac{d^2K_2}{ds^2}r^3+\frac{1}{128}\frac{d^4K_2}{ds^4}r^5+\cdots\right]\sin(2\varphi)+\cdots$$

Transverse Harmonics as a Function of s



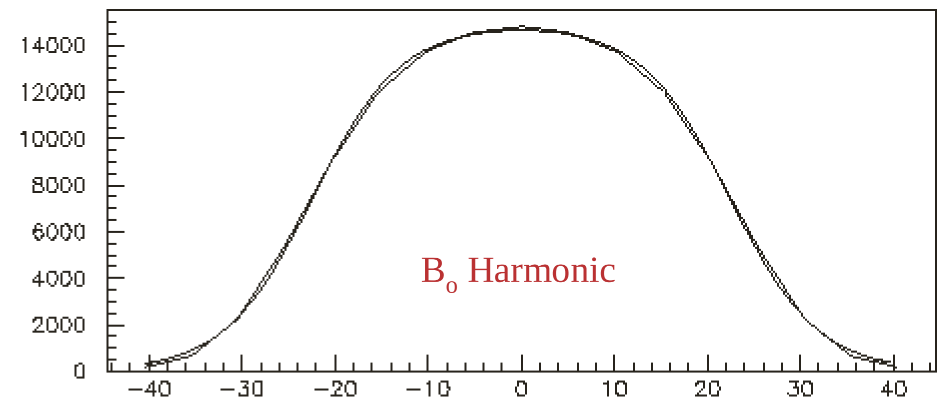




$$\frac{1}{B_o \pi} \oint B(\varphi) \cos(2\varphi) d\varphi$$

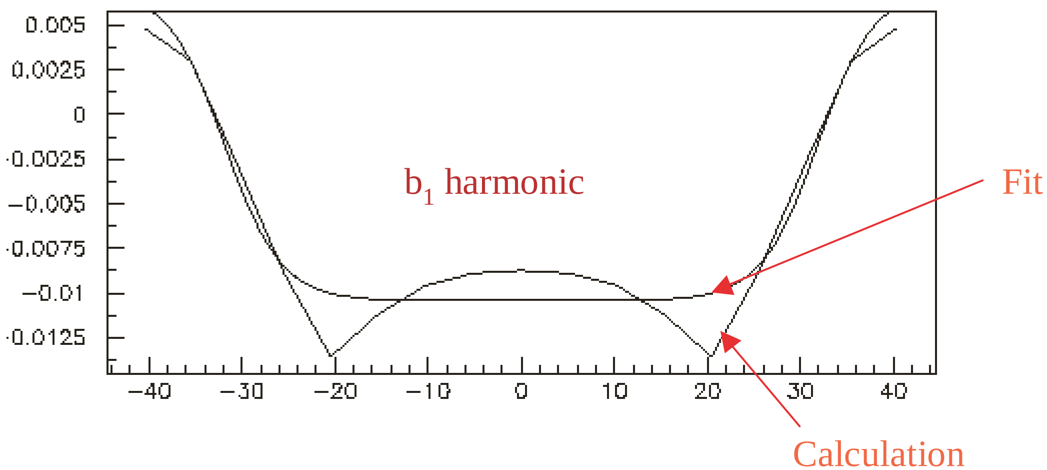
Calculated along the reference path

Dipole Profile Fits



Fit to

tanh[k(x-χ)]-tanh[k(x+χ)]



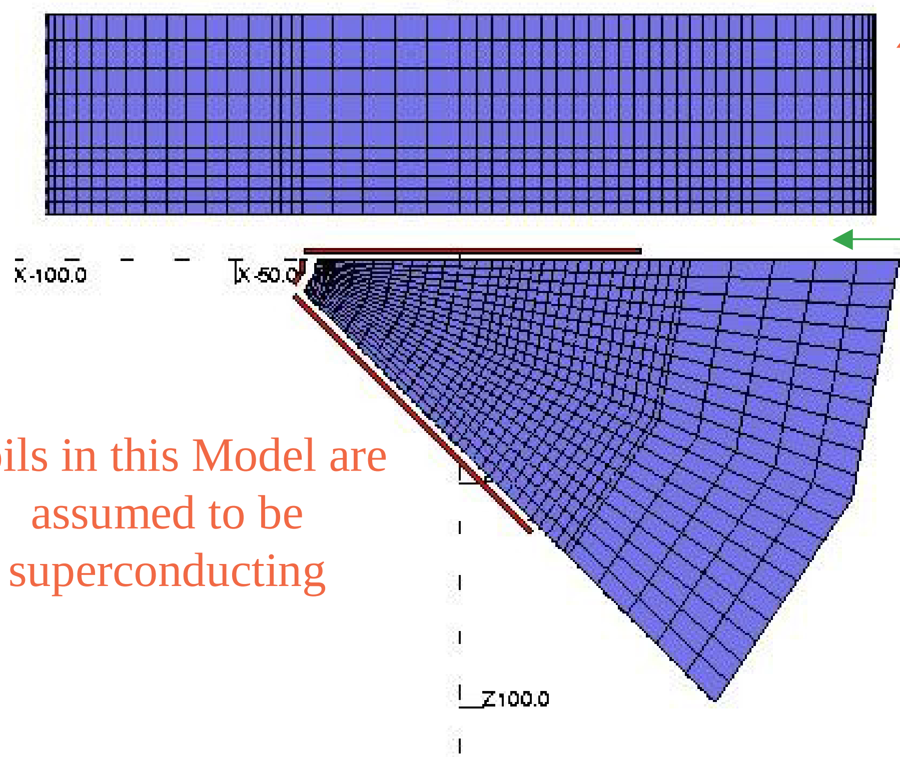
Tosca Model for Wedge Dipole

95 cm radius

End of Return Iron for Large Solenoid

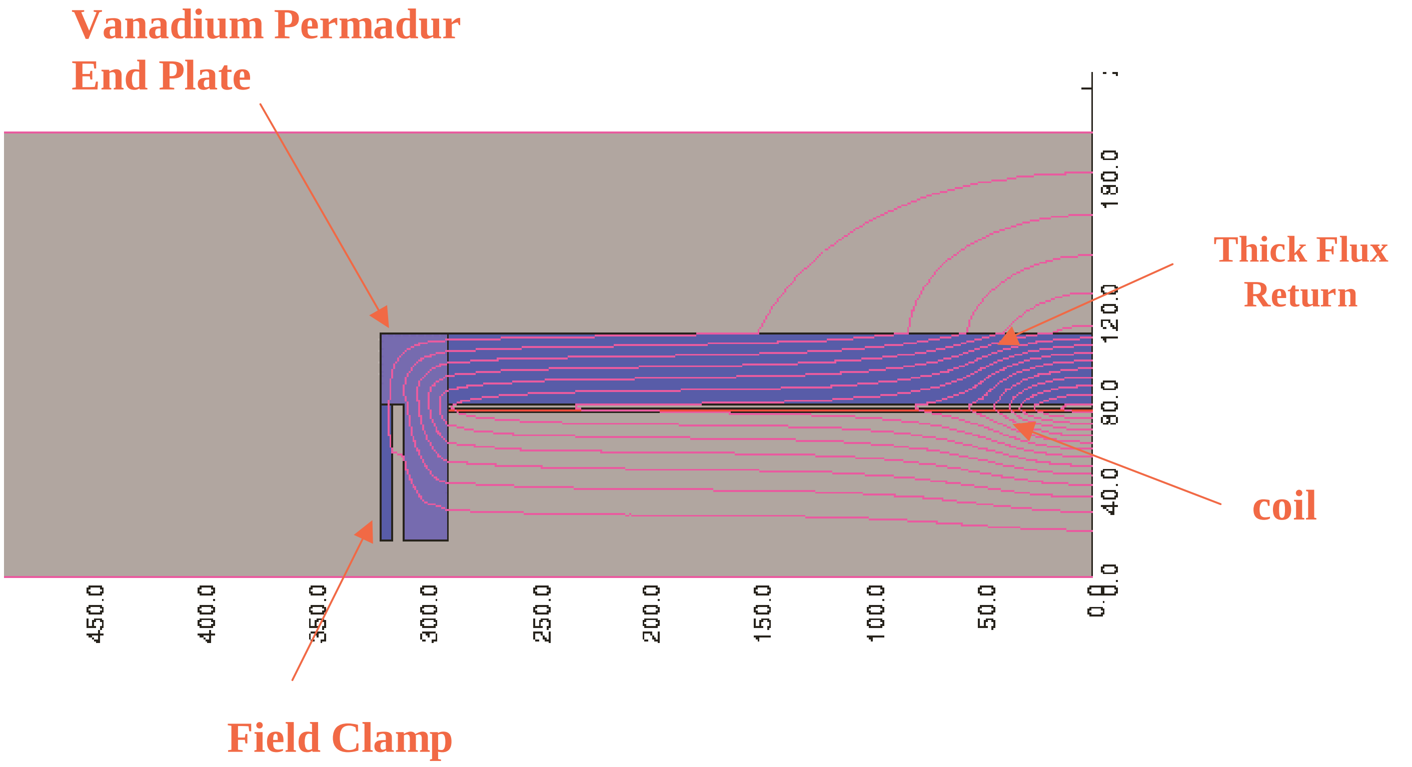
15 cm endplate

10 cm gap between dipole and shield

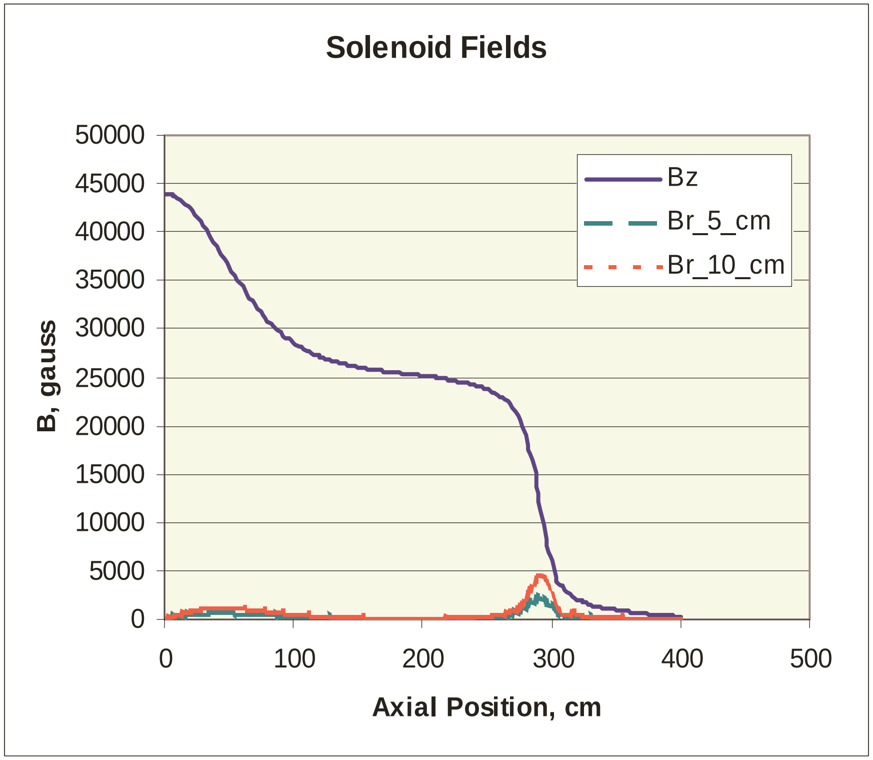


Coils in this Model are assumed to be superconducting

Long Solenoid Magnet



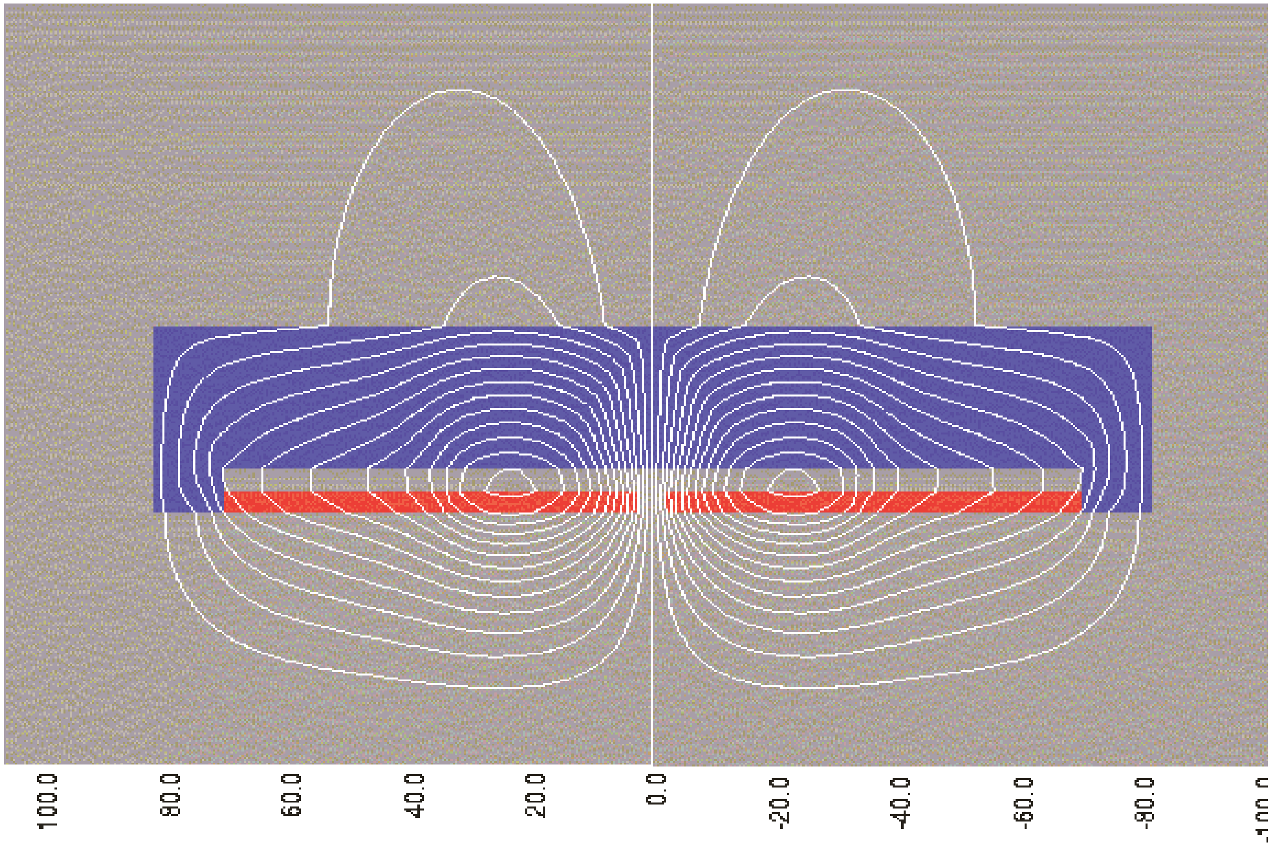
Fields in Long Solenoid



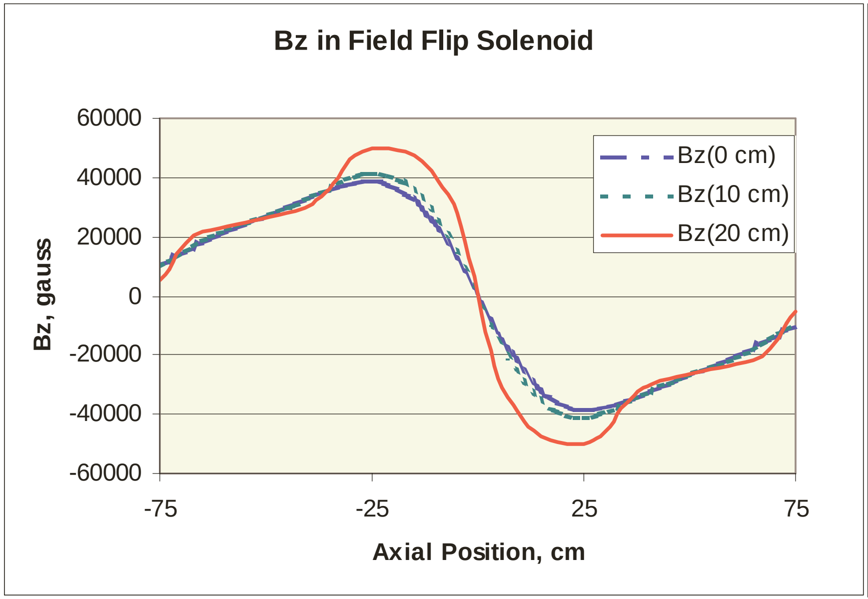
Comments on Solenoid Field

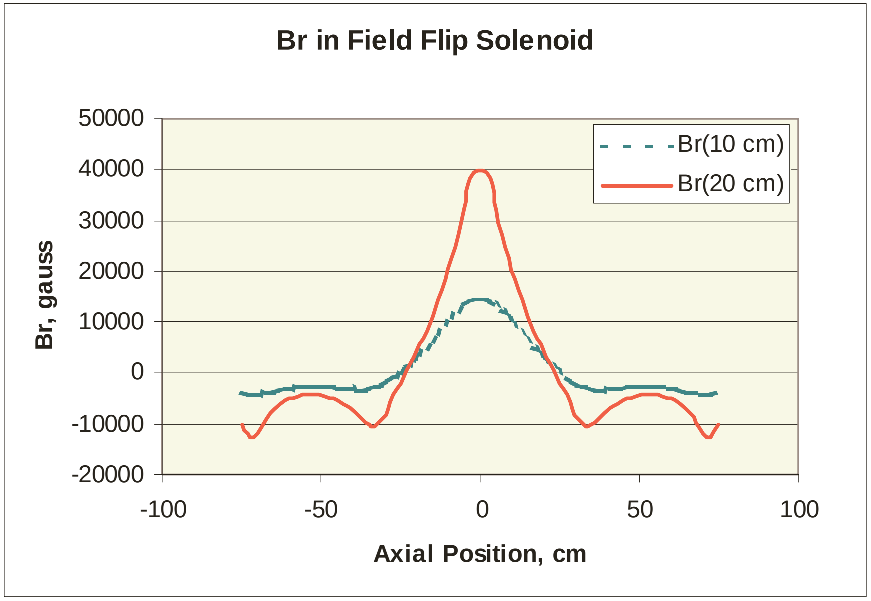
- The end plate effectively separates the solenoid field from the dipole for the case with small aperture coils.
  - This still has to be shown for the large coil case.
- Radial field are present only in vicinity of end plate.
  - Extend approximately one coil diameter (as expected).

Short Solenoid Magnet



Short Solenoid Fields





Field Maps

- The **TOSCA** program can generate 3D field grids.
  - Wedge Dipole
- Opera2D is used to generated the following grids with 1 cm$\times$1 cm segmentation:
  - Large Solenoid
  - Tail of Dipole in Large Solenoid
  - Tail of Dipole in Small Solenoid
  - Small Solenoid
- The **gufld** (or **guefld**) subroutine in GEANT will have to keep track of which octant it is in, which grid it should use and what signs to apply to the field for each point in space.

Field in Geant